

# Appendix S. First Surface Indications of Well Flow and Pit Gain

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## Introduction

Per OLGA® well flow modeling, the well started flowing at 20:52 hours while the rig crew was displacing the well to seawater. A review of real-time data, witness interviews and testimony was conducted to assess mud pit volume, well flow rates and pressure increases on April 20, 2010, between 20:52 hours and 21:08 hours.

## Witness Account

Notes from a witness interview with the BP well site leader indicate:

We then closed it [the kill line] in and opened the bag [annular preventer]. Got the pumps lined up. Told them to let me know when the pill comes up so that we could do a sheen test. I then went to the office and checked what calls I had. They called to say the [spacer] pill was back so I went to the rig floor.

## Excerpt from M-I SWACO Displacement Procedure

The *M-I SWACO Displacement Procedure* (refer to *Appendix P. BP/Deepwater Horizon Rheliant Displacement Procedure OCS-G 32306*.) stated:

- 8. When WBM [water-based mud] spacer returns at 15,968 stks, over-displace until interface is incorporated. When interface is incorporated, Compliance Engineer will take sample for Static Sheen Test and ROC and shut down pumps. Switch to overboard discharge.
- 9. If Static Sheen is an apparent pass, discharge remaining spacer and seawater down overboard line. Mud Engineer will advise.

## Sequence of Events

When the negative-pressure test was complete at 19:55 hours, the annular preventer was opened and the mud pumps were started, to continue the displacement of the synthetic oil-based mud (SOBM) and spacer out of the well with seawater. The M-I SWACO displacement procedure gave instructions to the rig crew to shut down the pumps when the spacer returned to surface and perform a sheen test to verify that the spacer met the criteria for discharging overboard. (Refer to Figure 3 on page 6 and Figure 4 on page 7.)

At 20:52 hours, the pump rate was reduced in anticipation of the spacer coming back.

At 20:58 hours, the pump rate was further reduced, but the flow back volume increased due to the trip tank being emptied into the flow-line. It appears that a trip tank was being cleaned and the wash water was being pumped to the mud pits via the flow-line, which is the conduit from the riser. It was determined from real-time data that the drill pipe pressure started to increase at about this time (21:01); the drill pipe pressure should have continued to decrease as heavy fluid was pushed up the annulus and out of the well.

Between 20:58 hours and 21:08 hours, a gain of 39 bbls occurred just before the mud pumps were shut down for the sheen test. This was determined from Sperry-Sun real-time data.

At 21:08 hours, pumping stopped as the spacer returned to surface. The real-time data indicated that the flow out profile was different from what should have been expected, and that the well was flowing. During the period that the pumps were stopped for the sheen test, the drill pipe pressure continued to increase from 1,017 psi to 1,263 psi.

The flow anomaly and pressure increase appears to have gone unnoticed by the rig crew, as pumping operations continued soon after at 21:14 hours.

## Conclusions

The investigation team made the following conclusion and observation regarding the pit volumes:

- A gain in pit volume of 39 bbls occurred between 20:58 hours and 21:08 hours. The gain appears to have gone unnoticed by the rig crew.
- A pressure increase of 246 psi occurred over a 6-minute period while the pumps were shut down for the sheen test. The pressure increase does not appear to have been investigated by the rig crew.

## Supporting Analysis

### Pit Volume Calculations

The gain analysis during the riser displacement can be estimated using either pit volumes or flow rates; however, the investigation team considered pit volumes to be more accurate than flow rates.

Active pits #6, #7, #9 and #10 were being used during the displacement of the riser from mud to sea water. Seawater was pumped from the seawater chest (not part of the pit system), and mud returns were taken back to the active pits.

The trip tanks were pits #17 and #18. Two trip tank transfers occurred during the riser displacement (20:02 hours - 21:08 hours) to seawater. The first transfer did not appear to have been discharged down the flow-line, since there was no increase in flow-out. The second transfer did appear to have been discharged down the flow-line, and the increase in flow out matched that of the transfer.

*Table 1* provides specific measurements of the volume, time and flow rates for the trip tank transfer from pit #17 down the flow-line.

**Table 1.** Volume, Time and Flow Rate for the Trip Tank #17 Transfer.

Volume			Time			Flow Rate
Begin	End	Net	Begin	End	Net	Calculated
45.5 bbls	3.7 bbls	41.8 bbls	20:59:05	21:05:40	6.58 min	267 gpm

During the trip tank transfer, the flow-in from the rig pumps was 537 gpm for 6.58 minutes. Therefore, the volume pumped into the well would have been:

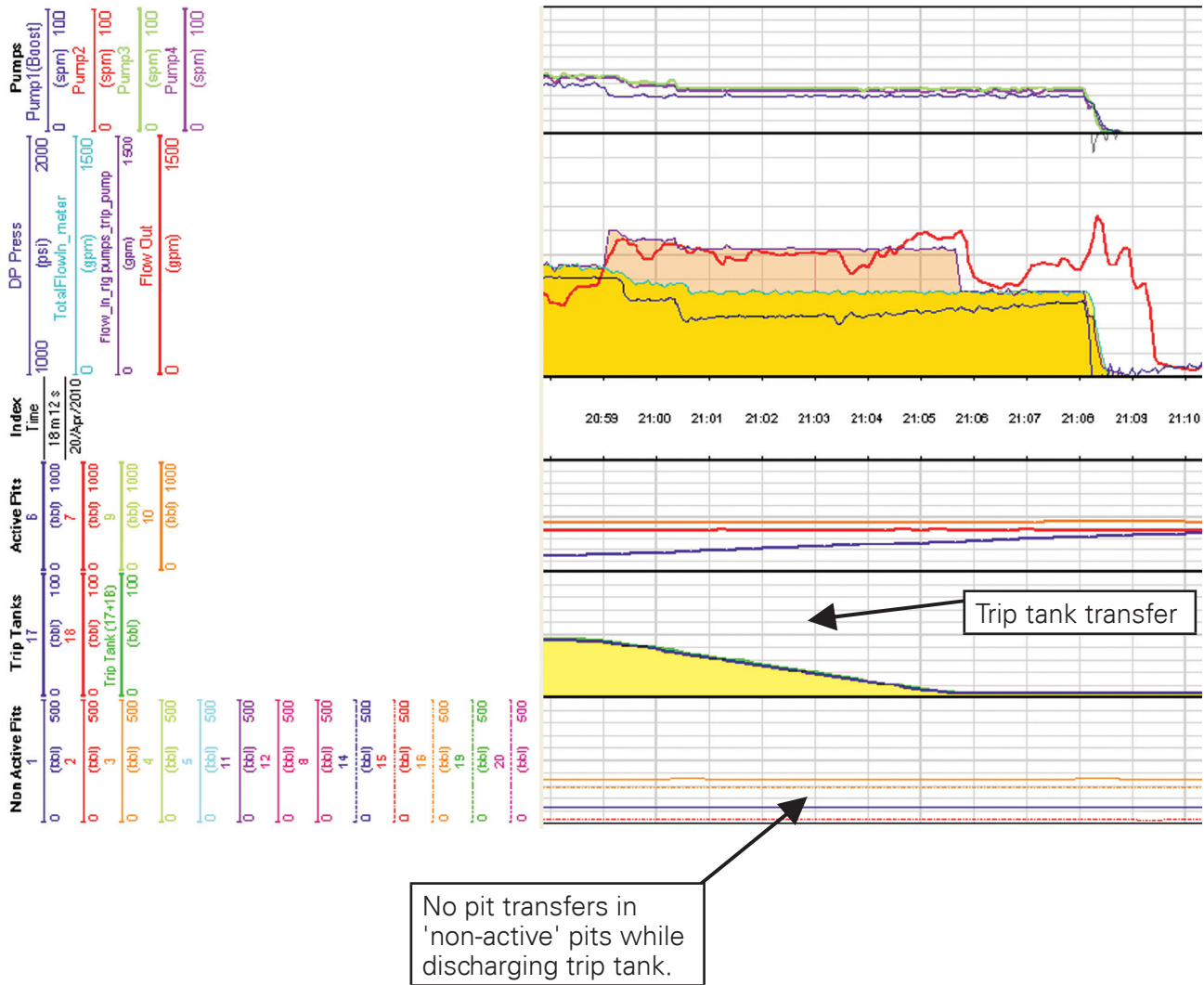
$$6.58 \text{ min} \times 537 \text{ gpm} = 3,533 \text{ gal, or } 84 \text{ bbls.}$$

The active pit system increased 119 bbls (1,488 bbls increased to 1,607 bbls) during the trip tank discharge (from 20:59:05 hours to 21:05:40 hours), which was an equivalent flow rate of 742 gpm. *Table 2* gives the specific measurements of the barrels pumped during this process.

**Table 2.** Volume (Barrels).

Action	Barrels
Active Pit Change	119 bbls
Flow In (Rig Pumps)	-84 bbls
Net Gain or Trip Tank Transfer	35 bbls

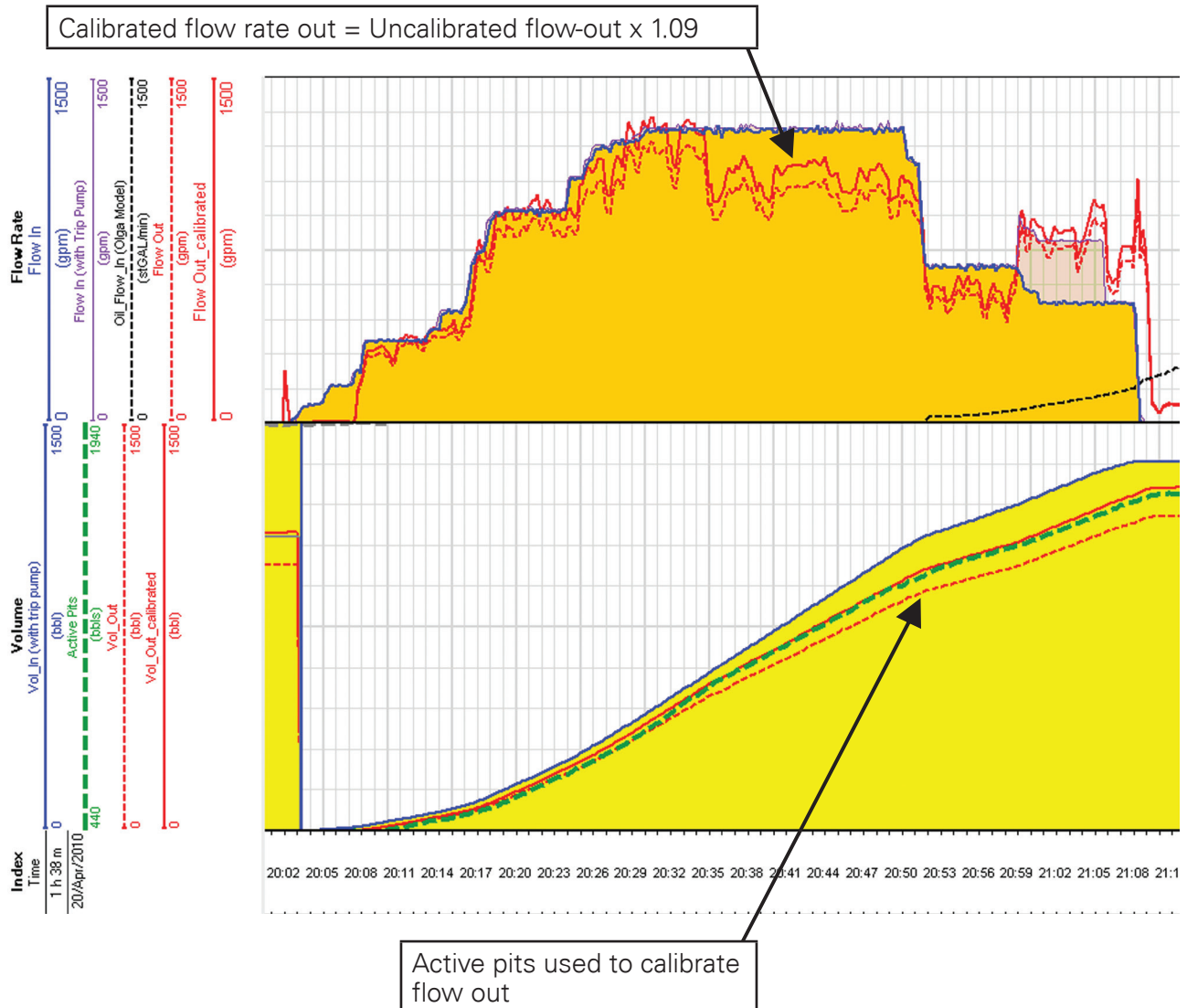
It was assumed that the 35 bbls gain was due to the trip tank transfer of 41.8 bbls. The assumption that the trip tank was discharged down the flow-line to the active system was supported by the fact that the real-time data does not indicate movement in any of the 'non-active' pits. *Figure 1* shows the lack of movement in the non-active pits.



**Figure 1.** No Movements in Non-active Pits.

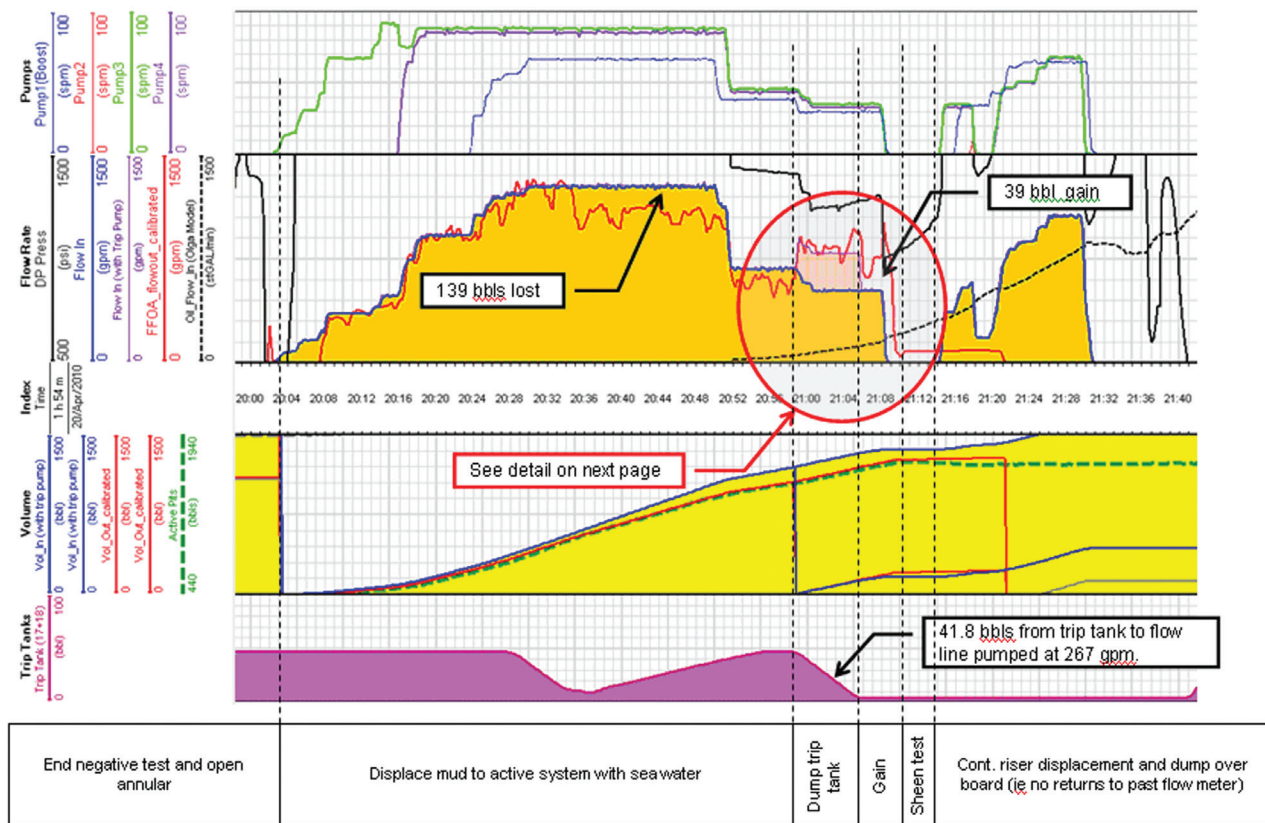
### Flow Rate Calibration

The flow rates out of the well should have been calibrated by Sperry-Sun to match the pit volume information. During the riser displacement on April 20, 2010, at 20:02 hours to 21:08 hours, data from the active pit system (pits #6, 7, 9 and 10) was used to calibrate flow-out. Seawater (from the seawater chest) was displacing mud in the riser to the active system. The investigation team used a 9% increase in uncalibrated flow-out to get a calibrated flow-out for the analysis based on this observation. *Figure 2* shows the calibration of the flow rate.



**Figure 2.** Flow Rate Calibration.

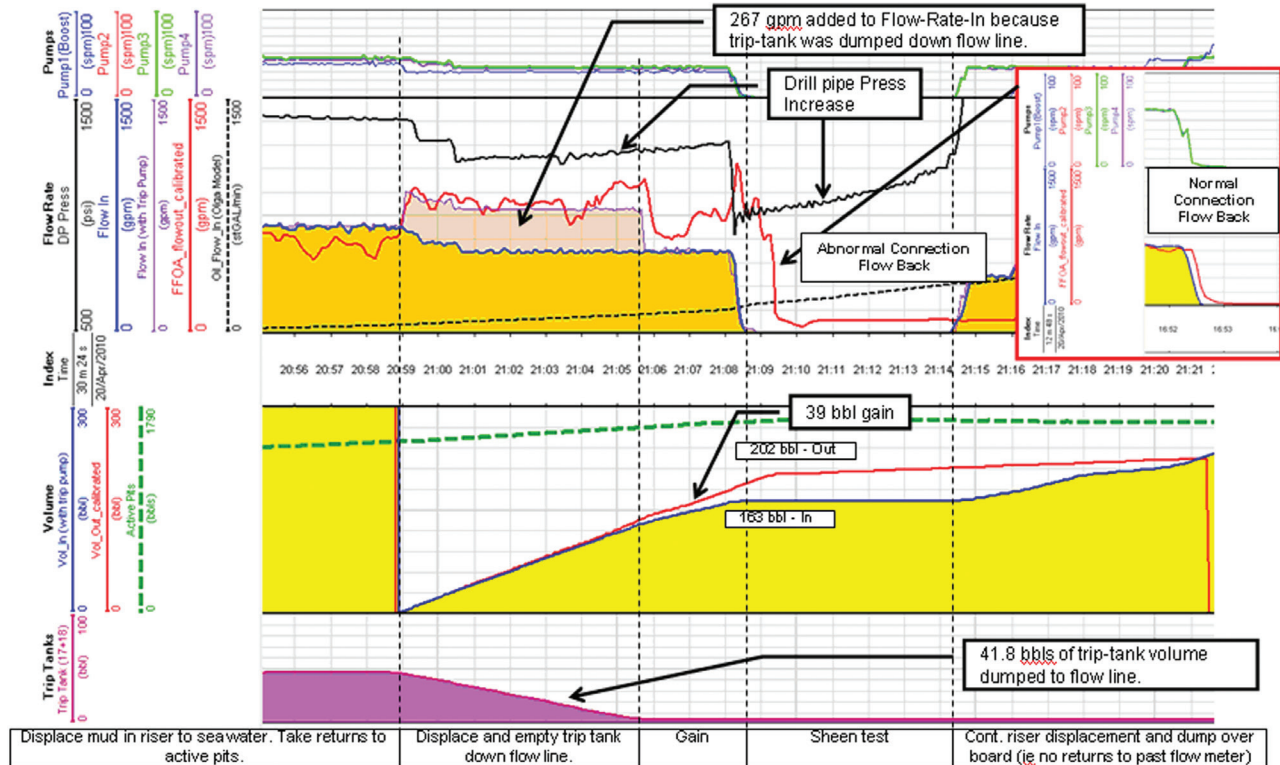
Figure 3 shows the gain of fluid at 21:08 hours.



**Figure 3.** Gain at 21:08 hours on April 20, 2010.

Operation from 20:00 hours to 21:08 hours opened the annular preventer and displaced the riser to seawater. At 21:08 hours, the pumps were shut down for a sheen test. During the final minutes before the sheen test, a gain of approximately 39 bbl occurred. Figure 4 shows the gain seen at 21:08 hours.





**Figure 4.** Gain at 21:08 hours on April 20, 2010; Detailed Analysis.

During operation from 20:58 hours to 21:08 hours, a 41.8 bbl transfer from the trip tank to the active system through the flow-line occurred. The 41.8 bbl of mud transferred from the trip tank was added to the volume of fluid pumped by the mud pumps, giving a total of 163 bbls. The calibrated flow out volume measured from the well was 202 bbls. The difference between these two volumes is the 39 bbls that was gained during this time period. Drill pipe pressure increased at 21:01 hours, even though the pumps were slowed. This pressure increase was the first sign of a gain at this time. When the pumps were shut down for the sheen test at 21:08 hours, the flow out was abnormally large, indicating a gain.